Carnegie Mellon
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Introduction to the CMMI® Acquisition Modu (CMMI-AM)

Module 3:
CMMI-AM and Engineering

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Agenda

Engineering Process Areas

- Requirements Development
- Requirements Management
- Verification
- Validation

Summary

PMO Role in Systems Engineering 1

Inherent PMO Responsibility:

- Ensure technology readiness level is appropriate for program phase
- Develop initial system requirements in conjunction with stakeholders and ensure continued involvement
- Develop technical evaluation criteria and evaluate proposals during source selection
- Develop independent cost and schedule estimates for the technical effort
- Ensure external interfaces are properly identified and monitored
- Ensure PMO has adequate systems engineering staff

PMO Role in Systems Engineering 2

PMO responsibility in conjunction with your contractor:

- Ensure contractor development method is appropriate
- Ensure contractor's systems engineering processes are acceptable and being followed
- Ensure compatible processes between prime and sub contractors and between the contractor team and the PMO
- Review and approve systems engineering documentation
- Ensure systems engineering function is adequately integrated with other areas such as logistics and test
- Manage the top-level change control process
- Perform technical evaluations
- Systems Integration (if applicable)
- Ensure end system meets requirements

Understanding Engineering PAs

The Engineering process areas establish a consistent set of requirements that are derived from stakeholder needs and operational capability statements so that work products developed internally by the acquirer and work products and delivered systems from the suppliers are proven to successfully satisfy end user needs and provide operational capabilities.

- **Requirements Management** **REQM**
- **Requirements Development** **RD**
- **Verification** **VER**
- **Validation** **VAL**

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Agenda

Engineering Process Areas

- Requirements Development
- Requirements Management
- Verification
- Validation

Summary

Requirements Development 1

The purpose of requirements development is to produce and analyze customer, product, and product-component requirements

Requirements Development 2

The purpose of requirements development is to produce and analyze customer, product, and product-component requirements.

For Acquisition, requirements development has two contexts:

- The amalgamation and coordination of the operational requirements (customer requirements) into a requirements set that will define the scope and direction of the acquisition;
- The allocation and extension of the customer requirements and additional acquirer requirements (*e.g.*, architecture, formal and informal reviews, reporting or data requirements) that become the basis of the processes utilized by the supplier's organization.

Requirements Development 3

There is a continuous iteration of requirements down through the multiple tiers of requirements documents associated with the components of the system

- For example, requirements flow from the stakeholders to the system level to multiple subsystem levels and eventually to either hardware or software component levels

The responsibility for developing requirements across the levels is generally split between the acquirer and the supplier

- The acquirer is generally responsible for the higher level, starting with operational requirements and the supplier is responsible for successive levels below that

Poor Requirements Development …

Symptoms

- Unstated requirements or poorly stated requirements lead to confusion among staff and customers
- Design, implementation, and test work products inconsistently interpret the requirements
- It takes a long time to get agreement on product design

Why should we care?

- Unusable products and unhappy customers
- Wasted time and resources building the “wrong” product
- Staff members get tired of rework because requirements have been re-interpreted yet again
- Excessive spending to satisfy customer expectations

Requirements: Input or Output?

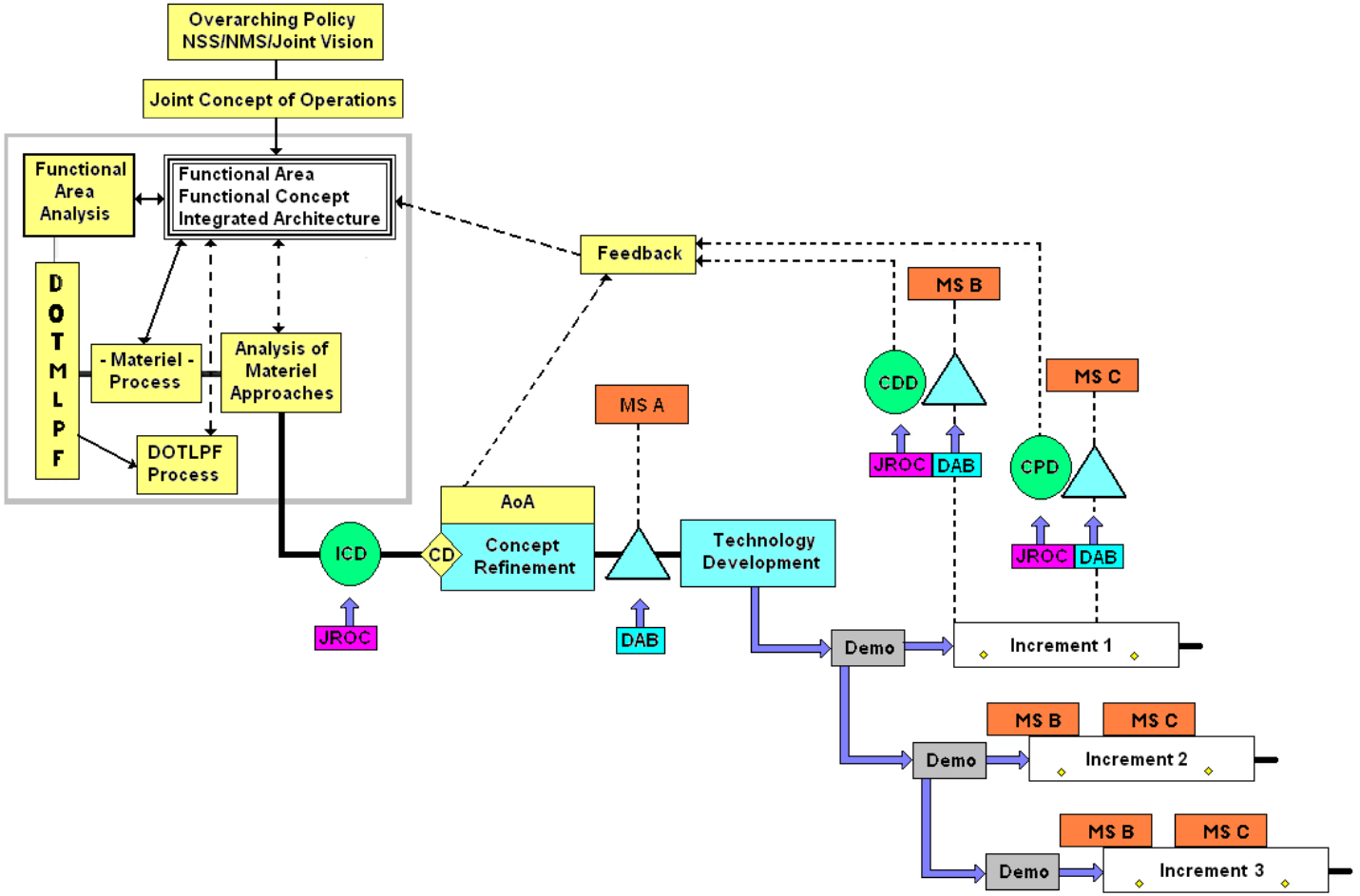
BOTH !

You **RECEIVE** requirements from your customer
- Operational needs

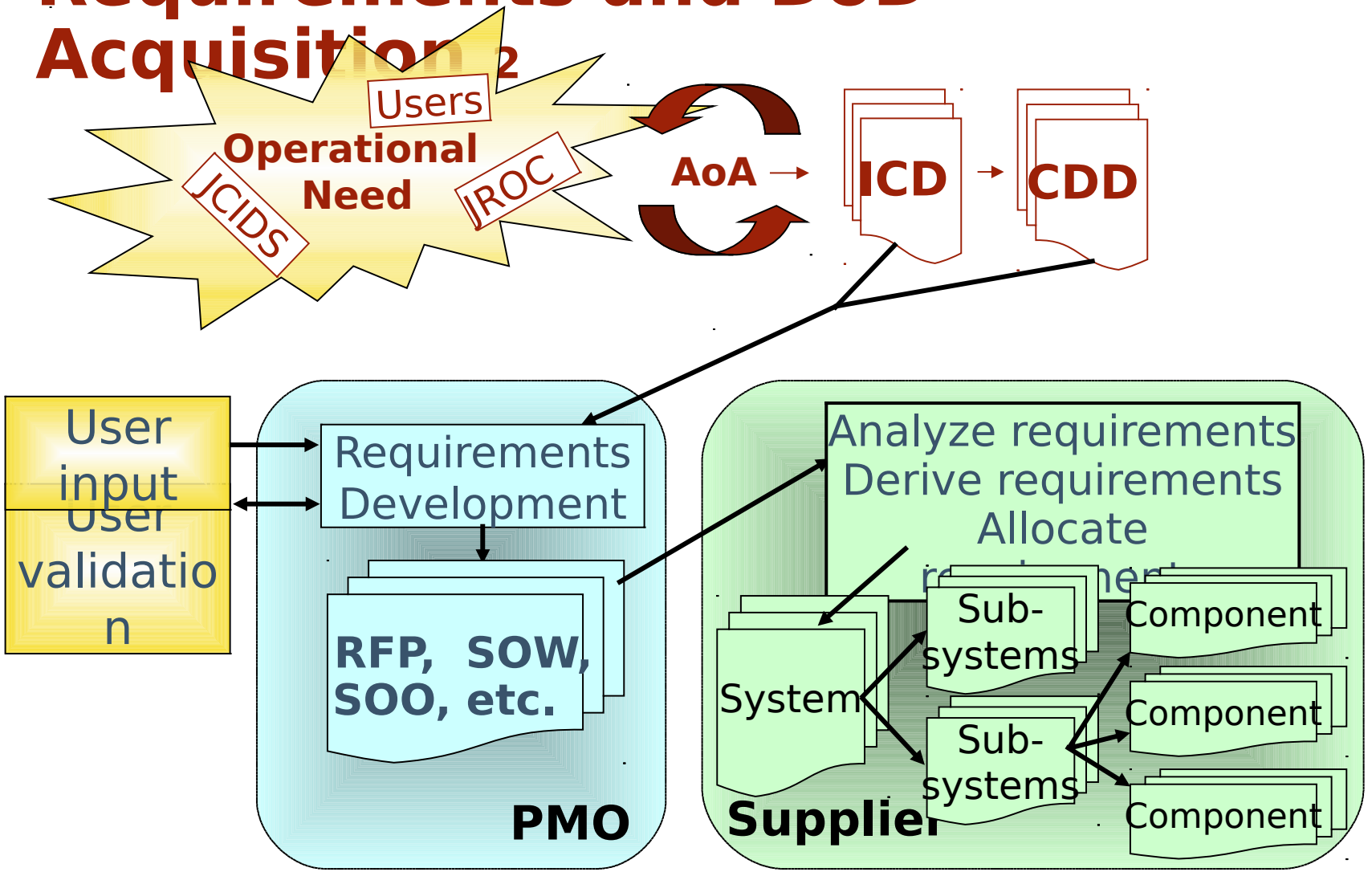
You **DELIVER** requirements to your supplier
- Through the solicitation, SOW, SOO, and/or contract

Your job is
- To ensure the quality of the inputs
- To convert the inputs to the high-quality outputs

Requirements and DoD Acquisition 1



Requirements and DoD Acquisition 2



Develop Customer Requirements

- Collect stakeholder needs
- Elicit needs
- Develop customer requirements

Typical Work Products

- Customer requirements
- Customer constraints on the conduct of verification
- Customer constraints on the conduct of validation

Sample Key Issues

Overly simplistic elicitation

Failure to identify / validate "root" of the requirement

Lack of attention to stakeholder requirements

Failure to involve all stakeholders

Develop Product Requirements

- Establish product and product component requirements
- Allocate requirements
- Identify interface requirements

Typical Work Products

- Product and Product component requirements
- Derived requirements
- Requirement allocation sheets
- Design constraints
- Interface requirements
- Relationships among derived requirements

Sample Key Issues

Failure to address critical product qualities & performance

Insufficient specification & under-standing of interface requirements

Forgetting to allocate all require-ments, including derived requirements

Failure to derive

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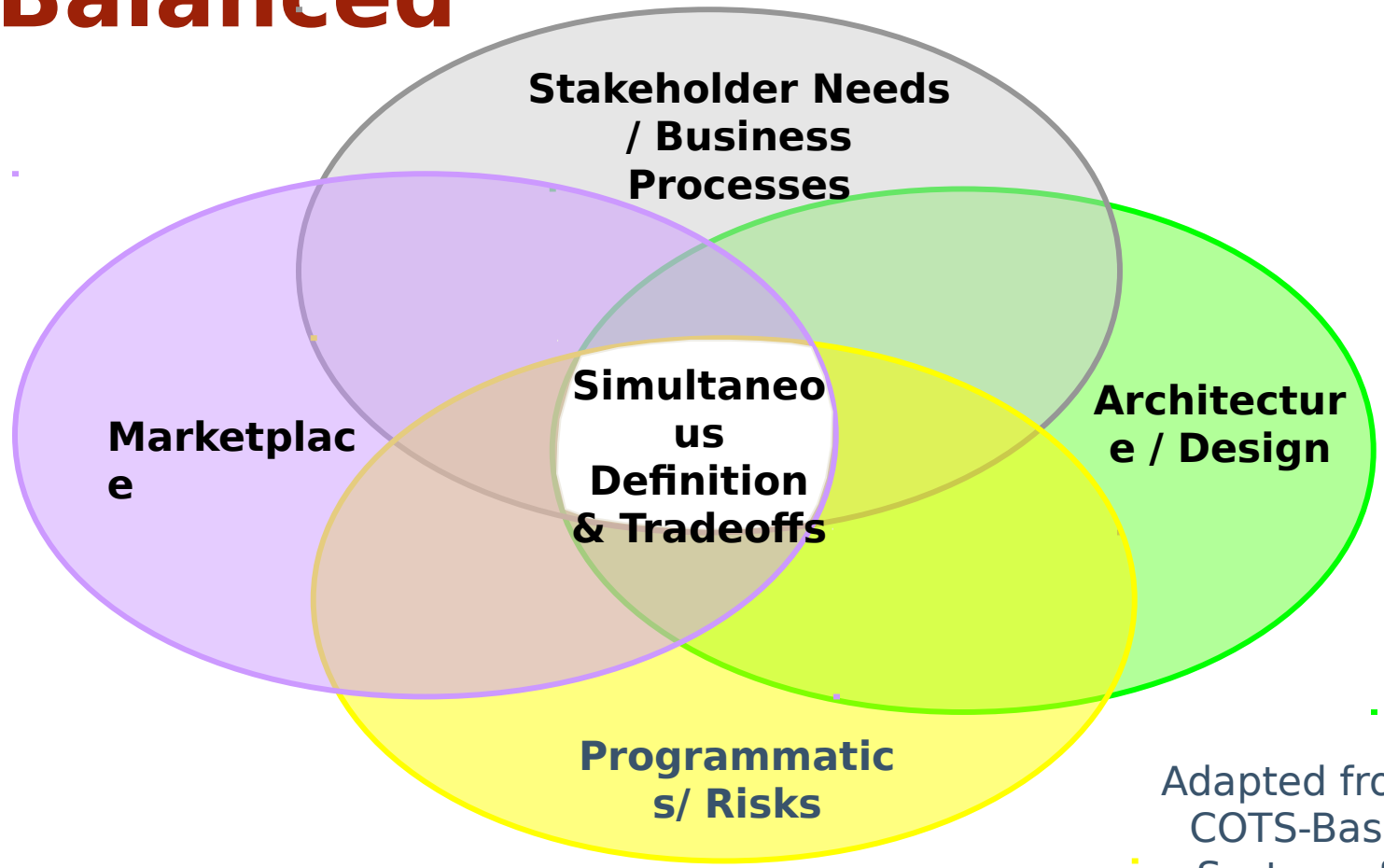
Requirements Must be Balanced



Adapted from COTS-Based Systems for Program Managers

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Analyze and Validate Requirements

- Establish operational concepts and scenarios
- Establish a definition of required functionality
- Analyze requirements to achieve balance
- Validate requirements

Typical Work Products

- Operational concept
- Product installation, operational, maintenance, and support concepts
- Use cases and activity diagrams
- Requirements defects reports
- Technical performance measures
- New requirements and proposed changes to resolve defects
- Assessment of risks related to requirements

Sample Key Issues

Insufficiently detailed Operational Concept

Not verifying requirements are complete, feasible, realizable, and verifiable

Missing required balance in requirements

Failure to use multiple techniques to validate the product will perform in the user's environment

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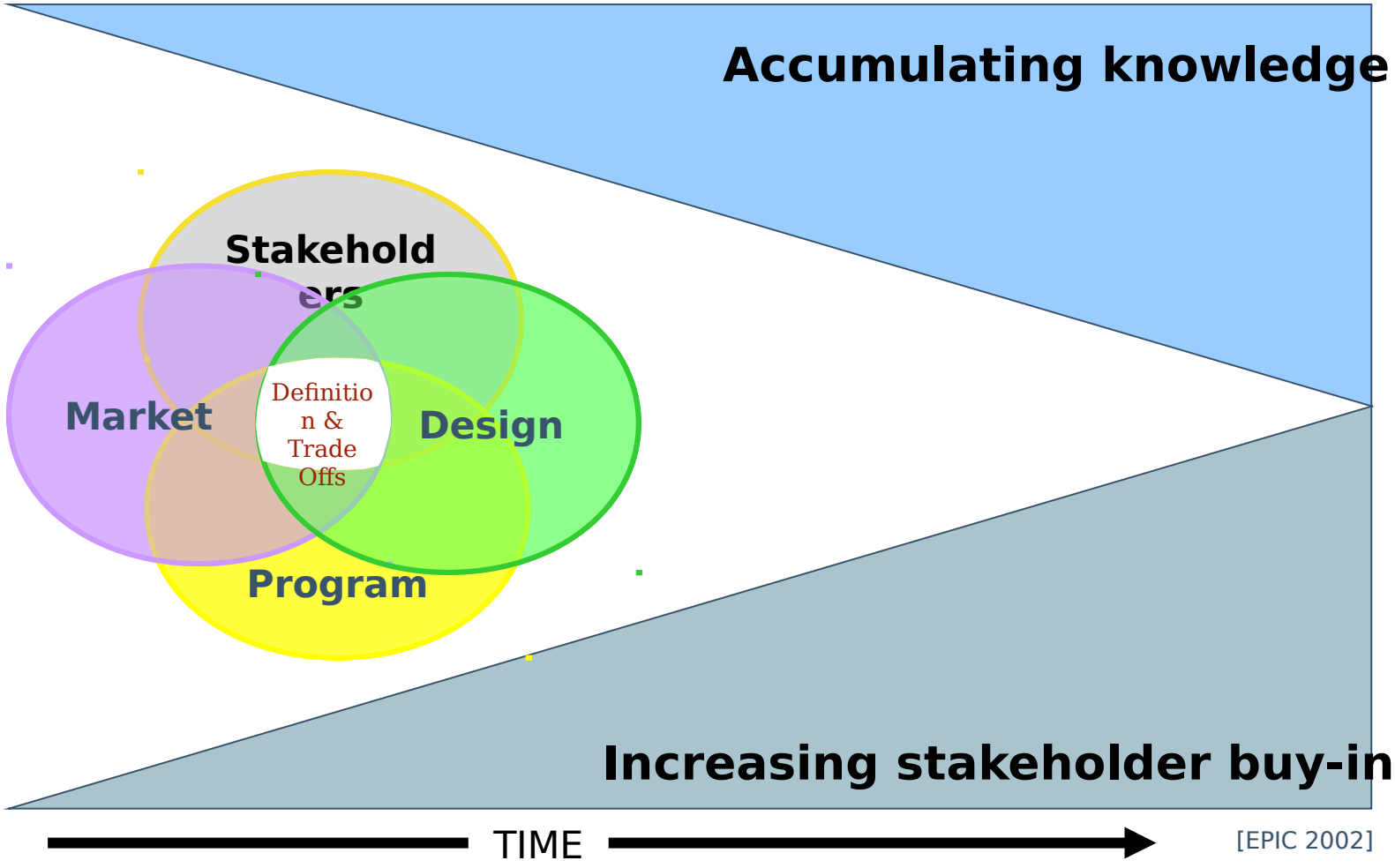
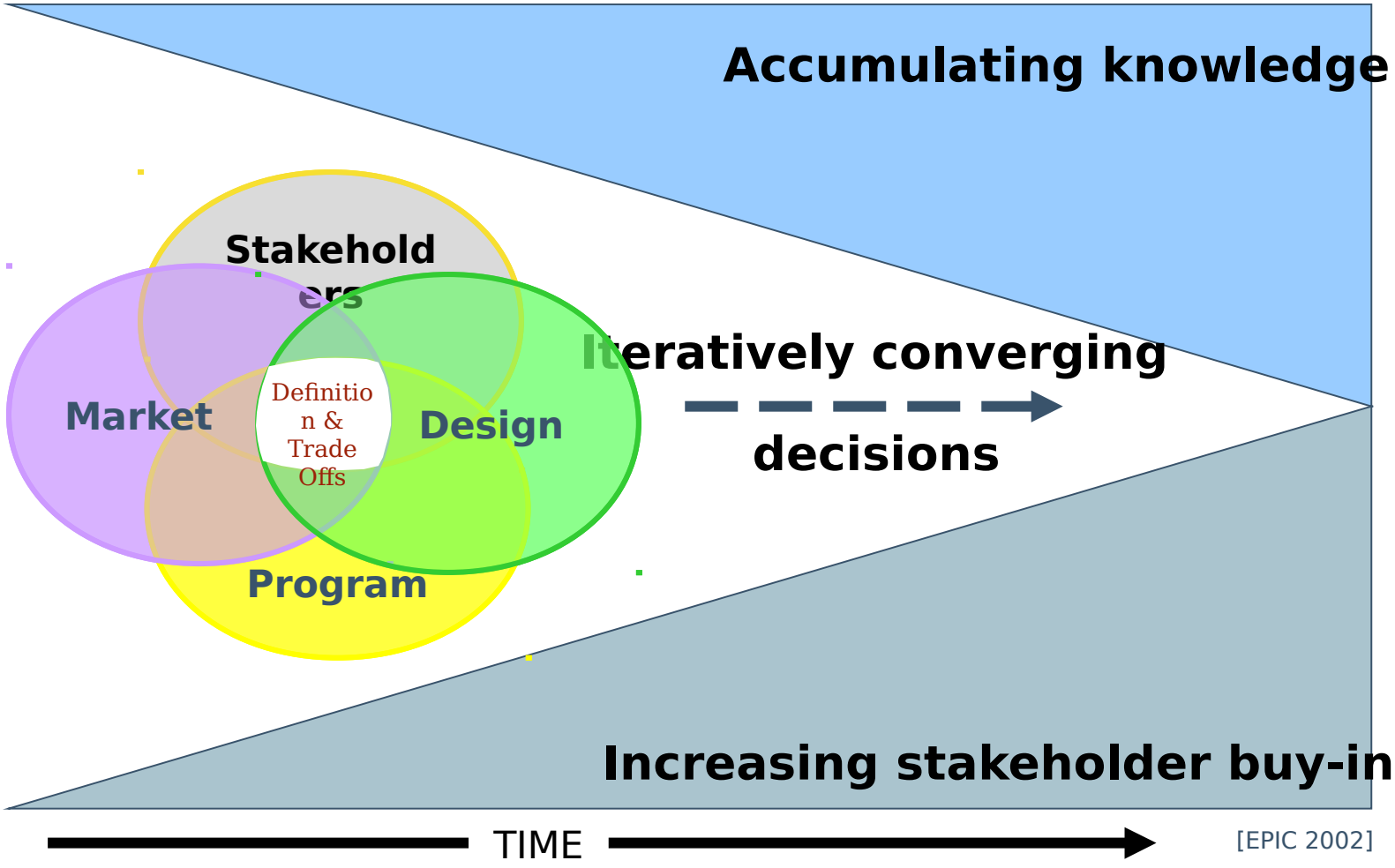
Requirements Must Evolve 1

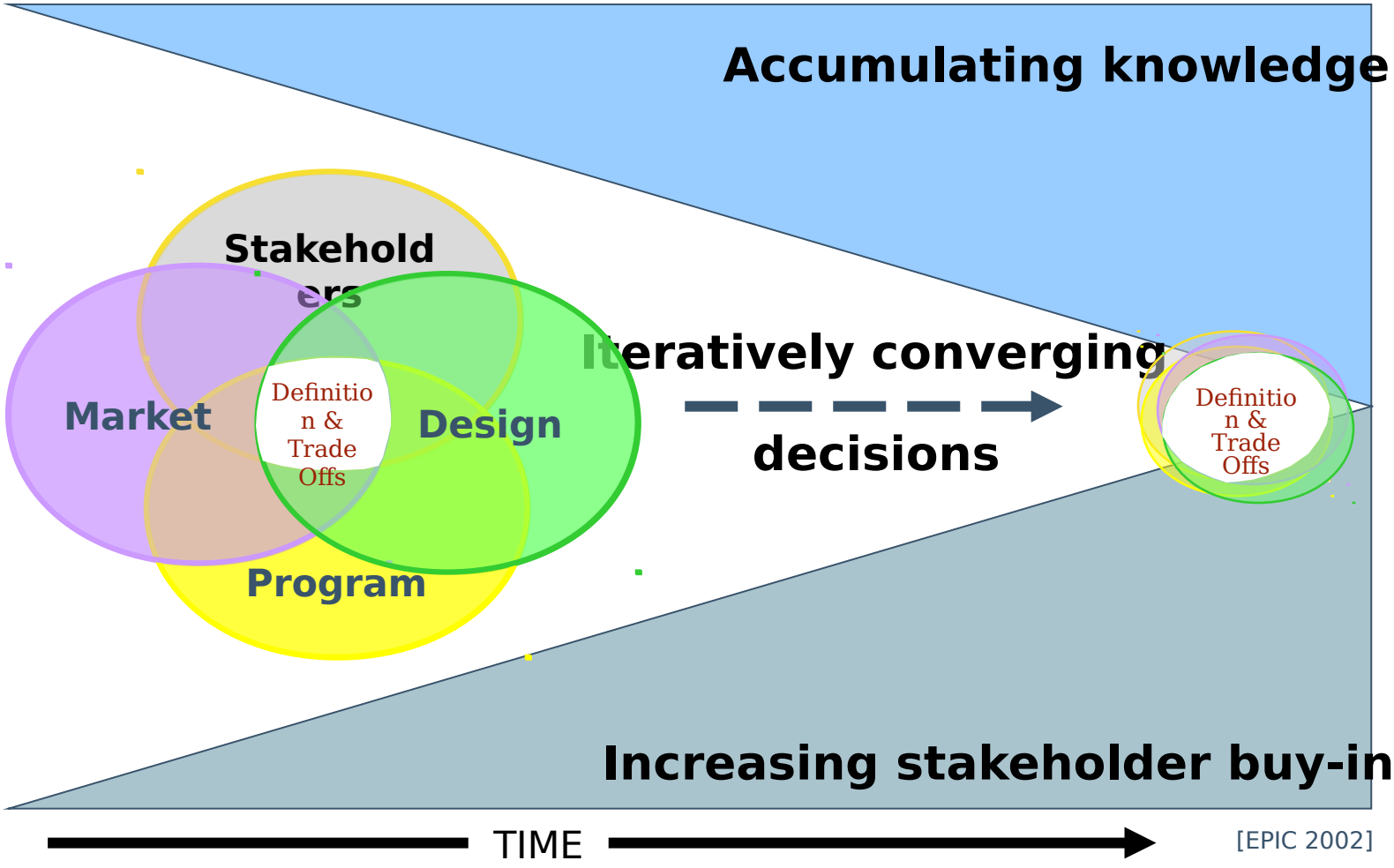


Requirements Must Evolve 2



[EPIC 2002]

Requirements Must Evolve 3



[EPIC 2002]

Requirements Development

CMMI-AM Goals and Practices 1

Specific Goal	Specific Practice
Develop Customer Requirements	• Elicit Needs • Develop the Customer Requirements
Develop Product Requirements	• Establish Product and Product- Component Requirements • Allocate Product-Component Requirements • Identify Interface Requirements
Analyze and Validate Requirements	• Establish Operational Concepts and Scenarios • Establish a Definition of Required Functionality • Analyze Requirements • Analyze Requirements to Achieve Balance • Validate Requirements with Comprehensive Methods

Requirements Development

Goal 1: Develop Customer Req'ts 1

Stakeholder needs, expectations, constraints, and interfaces are collected and translated into customer requirements

Elicit stakeholder needs, expectations, constraints, and interfaces for all phases of the product life cycle

- Identify stakeholders who are authorized to provide requirements
- Be sure to include users, testers, and maintainers
- Document all gathered information, including the source of the requirement
- Maintain involvement of the stakeholders throughout the acquisition

Requirements Development

Goal 1: Develop Customer Req'ts 2

Transform stakeholder needs expectations, constraints, and interfaces into customer requirements

- Transform into engineering-oriented requirements
- Ensure requirements are complete, consistent, clear, and unambiguous
- Document traceability to the elicited need
- Don't forget non-functional requirements such as reliability, maintainability, expandability, etc.
- Capture requirements for external interfaces
  - Particularly important for systems-of-systems

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Requirements Development

Goal 2: Develop Product Req'ts

1

Customer requirements are refined and elaborated to develop product and product-component requirements

Establish and maintain product and product-component requirements which are based on the customer requirements

- Part of this is your job. Part of it is your supplier's
- New requirements will be DERIVED from existing ones
- Ensure requirements are complete, consistent, clear, and unambiguous.
- Don't forget non-functional requirements such as reliability, maintainability, expandability, etc.
- Maintain traceability

Allocate the requirements for each product component

- Make sure that ALL requirements are allocated somewhere

Requirements Development

Goal 2: Develop Product Req’ts

2 Identify interface requirements

- Develop requirements for external interfaces
  - Particularly important for systems-of-systems
- Develop requirements for internal interfaces
  - Particularly important to ensure maintainability, modifiability, expandability, etc.

Requirements Development

Goal 3: Analyze and Validate 1

The requirements are analyzed and validated, and a definition of required functionality is developed

Establish and maintain operational concepts and associated scenarios

- Captures the inputs of your customer
- Used as a basis for requirements development and requirements validation

Establish and maintain a definition of required functionality

- Necessary to manage expectations of stakeholders
- Keep it up to date and widely available

Analyze requirements to ensure that they are necessary and sufficient

- Check for quality of the requirements
  - Complete, consistent, clear, unambiguous
- Check for traceability (forward and backward)

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Requirements Development

Goal 3: Analyze and Validate 2

Analyze requirements to balance stakeholder needs and constraints

- Trades between
- Obtain stakeholder buy-in on trades
  - you'll regret it later if you don't

Validate requirements to ensure the resulting product will perform as intended in the user's environment using multiple techniques as appropriate

- Key element to obtain stakeholder buy-in

Agenda

Engineering Process Areas

- Requirements Development
- **Requirements Management**
- Verification
- Validation

Summary

Requirements Management 1

The purpose of requirements management is to manage the requirements of the project's products and product components and to identify inconsistencies between those requirements and the project's plans and work products

For Acquisition, requirements management is applied to the requirements that are received from the requirements development process

Requirements Management 2

During acquisition, requirements management includes

- Direct management of acquirer-controlled requirements
- Oversight of supplier requirements management

Requirements are managed and maintained with discipline so that changes are not executed without recognizing the impact to the project

Requirements management does not end with the selection of a supplier and an award

- Acquisition project continues to manage high-level requirements, including changes
- Selected supplier manages the lower level requirements

Poor Requirements Management …

Symptoms

- High levels of re-work throughout the project
- Requirements are accepted by staff from any unauthorized sources
- “Galloping” requirements creep
- Inability to prove that the product meets the approved requirements

Why should we care?

- Solutions that don’t match user needs or may have to be replaced or retired early
- Inability to hold contractor to commitments
- Excessive budget consumption [LEFF 2003]
  - Requirements errors are the most common error and most expensive to fix
  - Requirements error are likely to consume 25% - 40% of the total project budget when not caught early

Obtain an Understanding of Reqts.

- Establish criteria for distinguishing appropriate requirements
- Establish objective criteria for the acceptance of requirements
- Analyze requirements to ensure that the criteria are met
- Reach an understanding of the requirements with the stakeholders

Typical Work Products

- Lists of criteria for distinguishing appropriate requirement providers
- Criteria for evaluation and acceptance of requirements
- Results of analyses against criteria
- Agreed to set of requirements

Sample Key Issues

Missing stakeholders

Lack of acceptance criteria resulting in inadequate verification, rework or system rejection

Failure to have a common understanding of requirements

Insufficient analysis

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Obtain Commitment to Requirements

- Assess the impact of requirements on existing commitments
- Negotiate and record commitments

Typical Work Products

- Requirement impact assessments
- Documented commitments to requirements and requirement changes

Sample Key Issues

Inadequate assessments

Existing commitments are not well known or defined

Failure to negotiate with balance in mind

Failure to obtain written commitment

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Manage Requirements Changes

- Capture all requirements and requirement changes
- Maintain the requirements change history with the rationale for the changes
- Evaluate the impact of the requirement changes from the standpoint of the stakeholders
- Make the requirements and change data available

Typical Work Products

- Requirement impact assessments
- Documented commitments to requirements and requirement changes

Sample Key Issues

Lagging documentation

Failure to plan for and manage the change process

Incomplete impact assessments

Lack of backup plans

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Requirements Management

CMMI-AM Goals and Practices 1

Specific Goal	Specific Practice
Manage Requirements	• Obtain an Understanding of Requirements • Obtain Commitment to Requirements • Manage Requirement Changes • Maintain Bidirectional Traceability of Requirements • Identify Inconsistencies Between Project Work and Requirements

Requirements Management

Goal 1: Manage Requirements 1

Requirements are managed and inconsistencies with project plans and work products identified

Develop an understanding with the requirements providers on the meaning of the requirements

- Be proactive to fully understand the intentions of the users
- Identify the “root source” of the requirement

Obtain commitment to the requirements from the project participants

- Written commitments from users, maintainers, testers, etc.

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Requirements Management

Goal 1: Manage Requirements 2

Manage changes to the requirements as they evolve during the project

- Apply rigorous configuration management
- Establish a change control board
- Establish a process to evaluate impact of proposed changes on cost, schedule, and performance

Maintain bi-directional traceability among the requirements and the project plans and work products

- Ensures that all higher-level requirements are addressed
- Ensures that all lower-level requirements arise from a parent requirement
- Indispensable for test planning

Identify inconsistencies between the project plans and work products and the requirements

Agenda

Engineering Process Areas

- Requirements Development
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- Validation

Summary

Verification *versus* Validation

Verification

- Are you building the *product right*?
- That is, are you meeting the specified requirements?

Validation

- Are you building the *right product*?
- That is, are you meeting the operational need?

Verification

The purpose of verification is to ensure that selected work products meet their specified requirements

For Acquisition, verification involves ensuring that the evolving work products of the acquisition project meet specified requirements for those products. The acquisition project should ensure.

- a proper verification environment exists
- work products are selected for evaluation based on documented criteria

Peer reviews are intended to be used for work products developed by the acquisition project

The acquisition project is also responsible for ensuring that the supplier uses appropriate methods to verify its work products

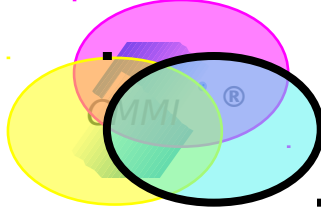
Poor Verification …

Symptoms

- There is disagreement among technical staff as to the "done-ness" of different components
- Under test the product doesn't meet requirements or design expectations
- Defects that could have been caught early escape into later life cycle phases
- There is increased integration or test time

Why should we care?

- Product reliability suffers if defects aren't detected or corrected prior to customer release
- The product costs more to test if early verification activities are ignored
- Customers don't want to pay for defective products, and you probably won't get their business next time



Verification 1

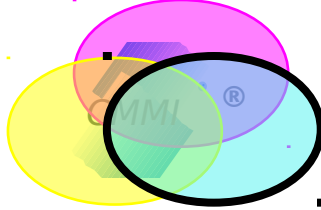
Activities to evaluate progress and effectiveness of evolving system products and processes and to measure specification compliance

Questions the PMO needs to address:

- Are the software test plans adequate?
- Has combined DT/OT testing been considered?
- Is the software/hardware integration testing rigorous?

Questions the contractor needs to address:

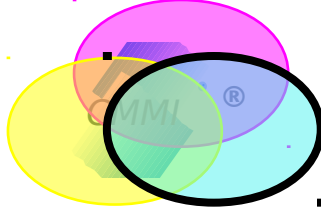
- Is there traceability from requirements to testing?
- Is testing started early and at the lowest possible level?
- Has independent quality assurance been involved in the test process from early in the program?



Verification 2

Software testing poses new challenges

- Various types of software products to be tested
- Many levels/types of software testing to be considered
- Software testing often focused on functional requirements only – don’t neglect non-functional requirements
- Software testing may require specific hardware, software and personnel test assets – PLAN AHEAD!



Types of Software To Be Tested

System software

User interfaces

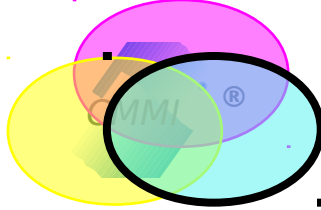
Modeling and simulation software

Training software

Communications interfaces

COTS products/interfaces

Programming Interfaces (extensions)



Levels of Software Testing

Peer reviews

Unit test

Integration testing

Interoperability testing

Security testing

Usability testing

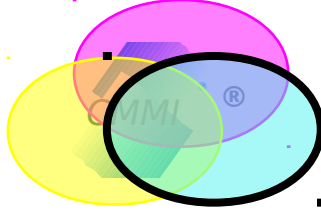
System testing

Acceptance test

Fall-back testing

Operational testing

Regression testing



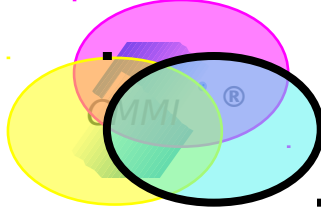
Robustness Testing

Software testing often focuses on functional requirements only

"**Happy Path**" testing is often the norm; **"robustness"** testing often overlooked

Many areas require robustness testing

- Load
- Stress
- Security
- Error detection and correction
- User inputs
- Graphical User Interface (GUI) structure
- Interfaces to other systems
- Conversions/limits/corner conditions
- Timing/Synchronization
- Memory usage
- Path coverage



Test Support Needs

Software testing may require specific hardware, software test assets

- Prototype hardware for early software testing
- Special test fixtures to test error conditions
- Interface mock-ups or emulators
- Special software for monitoring system performance
- Special software to test “abnormal” system conditions

Software testing may require specific test personnel

- Test team independent of the design team
- Users available for user interface testing

Verification

CMMI-AM Goals and Practices 1

Specific Goal	Specific Practice
Prepare for Verification	• Select Work Products for Verification • Establish the Verification Environment • Establish Verification Procedures and Criteria
Perform Peer Reviews	• Prepare for Peer Reviews • Conduct Peer Reviews • Analyze Peer Review Data
Verify Selected Work Products	• Perform Verification • Analyze Verification Results and Identify Corrective Action

Verification

Goal 1: Prepare for Verification

Preparation for verification is conducted

Select the work products to be verified and the verification methods that will be used for each

- Include work products of the acquirer as well as the supplier
- Typical verification methods include peer review, demonstration, inspection, testing, and analysis

Establish and maintain the environment needed to support verification

- Plan for staff, training, equipment, and facility needs

Establish and maintain verification procedures and criteria for the selected work products

- Maintain test procedures and acceptance criteria under configuration management
- Ensure traceability to requirements

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Verification

Goal 2: Perform Peer Reviews

Peer reviews are performed on selected work products

Prepare for peer reviews of selected work products

- Establish a peer review procedure
- Train the staff

Conduct peer reviews on selected work products and identify issues resulting from the peer review

- Notify reviewers and distribute materials for review far enough in advance to enable comprehensive review

Analyze data about preparation, conduct, and the results of the peer reviews

- Document results of peer review
- Assign responsibility and due dates for all actions

Verification

Goal 3: Verify Work Products 1

Selected work products are verified against their specified requirements

Perform verification on the selected work products

- Verify using approved procedures and acceptance criteria
- Document all test results (pass or fail)

Analyze the results of all verification activities and identify corrective action

- Document analysis and corrective actions
- Assign responsibility and due dates for all corrective actions

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- Validation

Summary

Validation 1

The purpose of Validation is to demonstrate that a product or product component fulfills its intended use when placed in its intended environment

Validation activities can be applied to all aspects of the product in any of its intended environments

- *e.g.*, operation, training, manufacturing, maintenance, and support services

The methods employed to accomplish validation can be applied to **work products** as well as to the **product** and **product components**

The work products (*e.g.*, requirements, designs, prototypes) should be selected for validation based on which are the best predictors of how well the delivered end product and product components will satisfy user needs

Validation 2

For acquisition, validation involves ensuring that the evolving acquisition work products (*e.g.*, RFPs, SOWs, plans) meet the acquisition project's needs

Validation activities are normally performed early and continuously throughout the acquisition life cycle

The acquirer also uses validation processes to ensure that the product or service received from the supplier will fulfill its intended use

The test community is a major stakeholder, participating in up-front planning through final-product acceptance

- The supplier and/or the test community may perform many of the validation practices, with the acquisition project facilitating the correction of deficiencies or enhancements by the supplier or follow-on maintenance organization

Poor Validation …

Symptoms

- Lots of user change requests are received before or soon after the product is released
- There are arguments among the technical staff as to what the user really wants
- The released product doesn't meet user expectations

Why should we care?

- Customers don't want to pay for products that don't meet their needs
- If an end user refuses to use the product as delivered, their confidence in you is eroded
- You'll spend a lot of money trying to make it right, or you'll give up that customer's future business

Validation

CMMI-AM Goals and Practices 1

Specific Goal	Specific Practice
Prepare for Validation	• Select Products for Validation • Establish the Validation Environment • Establish Validation Procedures and Criteria
Validate Product of Product Components	• Perform Validation • Analyze Validation Results

Validation

Goal 1: Perform Validation 1

Preparation for validation is conducted

Select products and product components to be validated and the validation methods that will be used for each

- Acquisition Strategy
- Supplier-developed requirements
- Delivered end product
- Support and maintenance plans
- SOW
- Test plans
- Training materials
- etc.

Establish and maintain the environment needed to support validation

- Plan for staff, training, equipment, and facility needs

Establish and maintain procedures and criteria for validation

- Maintain validation procedures and acceptance criteria under configuration management
- Ensure traceability to operational requirements

Validation

Goal 2: Prepare for Validation

The product or product components are validated to ensure that they are suitable for use in their intended operating environment

Perform validation on selected products and product components

- Verify using approved procedures and acceptance criteria
- Document all test results (pass or fail)

Analyze the results of the validation activities and identify issues

- Document analysis and corrective actions
- Assign responsibility and due dates for all corrective actions

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Summary

Summary 1

PMO plays a critical role in the systems engineering of a project

Principal goals of **Requirements Development**

- Develop Customer Requirements
- Develop Product Requirements
- Analyze and Validate Requirements

Principal goals of **Requirements Management**

- Manage Requirements

Summary 2

Principal goals of **Verification**

- Prepare for Verification
- Perform Peer Reviews
- Verify Selected Work Products

Principal goals of **Validation**

- Prepare for Validation
- Validate Product of Product Components